ARMY RESEARCH LABORATORY

Gelled Water Bag Cookoff Tests

by John D. Sullivan

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Abstract

Large tubular bags of water gel were tested as expedient barricades to provide protection against the effects of ammunition cooking off. The tests explored the feasibility of this concept for a program called Munitions Survivability Technology by the Defense Ammunition Logistics Agency. Primarily, the tests aimed to see if the bags could survive yet stop fragments from a time series of ground-exploded 105-mm high explosive (HE) projectiles. Second, the tests were used to evaluate the construction of the barricades. A six-bag (36-in diameter) and a three-bag (54-in diameter) linear pyramid barricade were constructed and subjected to four and nine rounds, respectively. The immature development state caused gel mixing and bag leakage problems, which were overcome. A single 36-in bag stopped a 105-mm fragment; however, the flow (runny gel) soon lowered the barrier height, losing protection against further cookoffs. The front wedge bag deflated and caused the incompletely restrained row above to roll down and drop the barrier height. The 54-in bags were easier to set up because there were fewer of them, but they reacted the same as the smaller bag barrier. The front ground bag deflated soon after the second shot (+6 min), and the top, unrestrained bag rolled down. Again, no 105-mm fragments got to the witness boards, but the barricade height was only about one partially deflated bag high.

Acknowledgments

Duane S. Scarborough of Defense Ammunition Logistics Agency, Picatinny Arsenal, NJ, served as the Program Manager for these tests. Jerry L. Watson and Robert B. Frey of the U.S. Army Research Laboratory, Explosives Technology Branch, provided valuable advice in test objectives and design.

Both barricade tests were supported by the Aberdeen Proving Ground (APG) Fire Department, with two truck crews who patiently stayed for days of troublesome bag filling. The 36-in bag test (September 1998) brought the fill supervision of Zvi Horowitz of Federal Fabrics-Fibers, Inc., Lowell, MA. Captain Karen Walters of the U.S. Army Corps of Engineers, Waterways Experiment Station (WES), assisted in constructing the barricade, a task taken up a year later by Toney K. Cummins. The 54-in bag filling (September 1999) was directed by Ken Flood and Mark D'antico of Federal Fabrics-Fibers, Inc., who troubleshot a gel mixer device. The ARL Test Director was Thomas C. Adkins. He was assisted by Timothy C. Cline and William H. Gault for both tests, and by Dawnn R. Saunders and John G. Lundy (both of Dynamic Science, Inc.) on the first test. Mr. Cline oversaw the construction of the mound, ramp, and firing table used in the second test. Video editing duties were assumed by Mr. Gault both times.

Appreciation also goes to Toney K. Cummins, who offered comments to the report, as did other WES personnel.

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1. Background

The test sponsor, Defense Ammunition Logistics Agency, initiated the Munitions Survivability Technology program to explore concepts for expediently protecting munitions stored in the open. The concept of a water bag barricade originated at Federal Fabrics-Fibers, Inc., Lowell, MA (Horowitz 1997a).

Ammunition may be stacked 7-ft high, making that the height requirement of the barricade. To allow time for progress in weaving large seamless tubes, the height was to be reached in stages. Three tubular bags of different diameters were stacked to form a linear pyramid barrier. The manufacturer demonstrated the 18-in diameter bags' robustness to air blast (Horowitz 1997b). The durability and construction of a pyramid of 18-in and 36-in-diameter bags were tested separately (Weathersby 1998). Fragmentation tests began at Aberdeen Proving Ground (APG), MD, on the 36-in size and on a 54-in size. The largest size gives a workable barrier that is a 3-bag pyramid. If weaving technology permits, a single 7-ft-diameter bag may be preferable.

2. Test Overview

This report details water bag tests conducted at APG that approximated the effects of ammunition cookoff (Hazard Class 1.3) in a fire. Projectiles were periodically exploded near a barricade that was formed from long tubes holding gelled water, and the effects were noted. If a bag took one large fragment hit, plain water would pour out, but the cookoff would continue; the gel satisfied this concern. A midpoint test was conducted in September 1998 on the 36-in bags, partly to determine whether it was feasible to evaluate the full-size, 54-in bags. The 54-in bags were tested in September 1999. The objectives of both tests relate to barricade construction and the effects of cookoff. Therefore, emphasis centered on the bags' construction, their ability to receive repeated explosions, and whether fragments would pass through them.

Another severe threat to stacked munitions is the sudden, complete detonation of a stack, causing the chain reaction destruction of other stacks (HC 1.1). This different hazard was tested on a barricade constructed from the 54-in size bag at the Naval Air Warfare Center, China Lake, CA, (Sullivan et al. 2000).

3. General Plan

Wood boxes containing two full-up M1 cartridges (projectile, propellant bags, and case) are normally banded four boxes to a layer and six layers high to a forklift pallet. These pallets are grouped and often stacked at a storage location. The gel bags were proposed as an expedient obstacle that might prevent an explosion from spreading to adjoining ammunition stacks. Only the projectile was used, the part which creates the explosion-spreading fragments. The propellant could not be used for two reasons: (1) the risk of burning propellant grains would have caused a wait before hooking up for the next shot, and (2) unburned grains, engulfed by spilled gel, would have made the gel a hazardous waste, causing grave environmental entanglements. The objective of the test was to determine if large bags of gel could survive while stopping fragments from a time series of exploded shells. To investigate the bags' capability to do this, a bag barrier was erected 10 ft from a line where single, 105-mm, TNT-filled projectiles were successively fired. Between firings, plywood sheets placed behind the barrier were inspected for fragment marks. Tests using both sizes followed an operations plan for the 36-in-diameter bag test, which can be found in the Appendix. Details are recounted as reminders of status and do not represent the state that a practical system would have.

4. 36-in Bag Test

4.1 Filling. The setup and filling of the 36-in bags are shown in Figures 2-6. The bags are seamless tubes, 3-ft diameter x 24-ft long, filled through a 3-in ball valve with a quick connect fitting. The outside cover is woven Kevlar, 3000 denier up from the thinner 1500 denier fiber used in WES tests. The inner bag is thin plastic, unattached to the outer cover except at a butt plate and at the fill valve. The empty bag weighs 45 lb. The capacity is nominally 1,200 gal or 10,000 lb of water.

Figure 1 shows the setup of 3-ft-diameter bags in a 3-2-1 pyramid, begun 14 September 1998. Bags were laid on a leveled gravel bed. The bottom row consisted of two wedge bags strapped together, with three large bags placed between them. Wedge bags are "bumps" that keep the large tubes from rolling apart. All ground bags were partially filled the first day. Water was pumped from a fire department tanker truck, which was periodically replenished by a crash truck that was refilled from a distant water hydrant. WES provided an adapter to connect fire thread to the Banjo Instant-Lok fitting on the bags.

The gel was Stockhausen AP85 superabsorbent polymer, which is used on crop fields to store moisture and as the absorbent in diapers. Since the chemical causes no health or environmental problems, the posttest plan was to spread it on the field to decompose in the sunlight. Nevertheless, APG environmental personnel were greatly alarmed; it was scooped up with a bucket truck and put in drums. The inner bag sides were stuck together and had to be pulled apart before powder could be added through a makeshift funnel made of a 5-gal water bottle (its bottom sawed off). Gradually, two 50-lb bags (or 1% weight) of powder were poured into the bag and shaken. Dispersing the powder throughout the bag was a tiresome process that went slowly on the two hot days of filling. The process was eased some after moving atop a high-sloped earth berm, adding the powder, and shaking it down the bag.

On the ground bag nearest to the firing line, the sticky sides were separated with an air hose. The bags did not have a bleed valve, since the stickiness problem was not anticipated. It was realized that a compressed air layer, probably small, was at the top of that bag, offering no fragment resistance. The forced air was not used again; the sides of the other bags were separated by hand. A good labor saving move is to use just enough air to break the stickiness, while still allowing powder dispersal. (In bags tested with bleed valves, a leaf blower fully inflated the bags, permitting easy placement before displacing the air with water.)

Because they are the retainers for the stack, the strapped wedge bags were filled first, followed by the two outer bags. The middle bag ended up being squeezed by the outer bags, producing an uneven height that made it impossible to lay the second row. Zvi Horovitz from Federal Fabrics

recommended filling it up; the increased water weight caused the bag with the bulged middle to drop in place, tightening all three bags against the wedge bags. Concern about overfilling and rupturing the bags under the weight of the upper bags made us cautious. Attempts to move the half-up bags by logrolling them was unsuccessful. (Eventually, there would have been an attempt made to chain and drag the bags to spread them, which might have also torn them open.)

On day two, the second row was laid; soon thereafter, the nearer bag spontaneously ruptured internally, sending numerous narrow streams of water around. (Perhaps later the gel would have sealed the porous outer skin.) The leaking bag was chained and pulled up and away with a crane. Surprisingly, with perhaps 5,000 lb of weight, the Kevlar did not tear. The top bag went into the empty spot. By the next morning, a rush order for more powder was met, and a backup, 1500-denier bag finished the stack, as shown in Figure 2. Without the powder, the stack's top bag would have been filled with water.

4.2 Firing. For each shot, ground zero was slightly different, mimicking 1-D scattered shells in a fire exploding over time. The plan was to detonate one round every 6-min, for a maximum of 10 rounds; the actual rate was one round every 3.5 min for four rounds. The barricade intactness was monitored on television and inspected between shots; firing would be stopped if gross failure occurred. Projectiles of 105-mm artillery rounds were statically detonated along a line 10 ft away and parallel to the side of the nearest 3-ft-diameter bag. The explosive train was dual detonators, low voltage 2023, inserted in a plastic holder. This also held a PBX booster pellet, 0.5-in diameter x 0.5-in long, with the holder pressed into C4, which was pressed into the projectile fuze well, as shown in Figure 2. A single firing line was twisted and taped to the detonators' wires. Projectiles were laid at positions prepainted on a metal plate at the bag pad height. Firings were made 3.5-min apart, and firing ceased after four rounds because the gel drained out of the ripped bag and overflowed the firing position.

4.3 Results. The shot-by-shot results for the 36-in bags are in the last column of Table 1 and are shown in Figures 3-6. Shot 1 put five equispaced holes (caused by shell fragments or rocks thrown up by the blast) into the wedge bag, and gel began to flow (see Figure 3). Shot 2 perforated

Table 1. Results on 36-in-Diameter Bag Barricade

Shot	Projectile on 10-ft Separation Line	Result
1	centered, nose on to bag (0°)	One large hole in front wedge bag (FWB), at -2/3 L. Four jetting holes in ground bag, One at front, two at -1/3, one at -2/3 L. Second-layer bag has two jetting holes at -1/3 and -2/3 L.
2	-2 ft, nose on to bag (0°)	Much gel on ground at start. Frags hit front of puddle. Bags not hit. Front bag rolls forward due to deflated FWB. Second-layer bag rolls into its place. Top bag rolls into second bag's position. Result: four ground bags and a second layer of bags. Front ground bag is half deflated.
3	centered, turned 30° counterclockwise (CCW)	Large gel splashes from front-bottom bag and second-layer bag. Large rip or maybe two at front bag. Gel gushes out. Ground bag deflated entirely at front. Next ground bag behind it still up. Front second-layer bag deflated entirely. Result: five bags on ground, only one second-layer bag, at declivity of two rear ground bags.
4	-2 ft, side on to bag	Upper bag takes very large hit near center. Front ground bag also hit. Huge gel pool overflows firing plate causing test to end. Three bags still up on ground. No fragment holes in plywood witness boards.

a second-layer bag (Figure 4), and shot 3 tore a large hole midbag (see Figure 5). The bags made at least one significant movement when the front wedge bag deflated moments after shot 2. With that sole restraint gone, the pile rolled, leaving only a single bag on the second layer. The bags rolling down caused a discontinuous loss of height, in addition to the steadier loss from flowing gel. Two rear ground bags were unaffected by the shots and still offered protection (see Figures 5 and 6). The amount of gel coursing over the area might have offered the unexpected benefit of putting out fires in packing boxes or smothering unburned propellant, but firefighters would not enter such an arena anyway.

A posttest inspection of the witness boards showed that no fragments passed through more than one bag. Only four fragments were recovered. To prolong the test, the shells were intentionally pointed in a direction to minimize fragmentation effects. For instance, shot 1 was nose on, and only the small fragments around the cone shape could have struck the bags; the large fragments from the

projectile body were traveling in a direction 90° away from the bags. Accordingly, the number and size of the fragments are largest when the projectile is pointed parallel to the barricade.

A posttest inspection of the pool of gel running out of the holed bags showed that the powder did not mix evenly with the water. There were numerous undissolved lumps of powder after the test. (The labor and mixing problems were tackled in the next size test by introducing a hopper device for mixing powder and water.) Additionally, sprinkling road salt over an area quickly liquefied the gel. A mound of salt did not affect the gel, except on the edge of the salt zone. These effects imply that an accident cleanup could be done fairly easily. Also, bags could be reused by liquefying the gel and allowing it to flow out of the nozzle. A saltwater solution pumped from a drum to a long sprinkler pipe would liquefy the mass in the bag. Bag recovery is another unexpected benefit implied by this test.

5. 54-in Bag Test

5.1 Filling. The setup and filling of the 54-in bags are shown in Figures 7-8. The 54-in diameter tube was closed at the front and back with heavily stitched circular pieces, but weaving a seamless bag is feasible. The bag covers were woven of 3000 denier Kevlar. Unlike before, the filling ball valve was at the edge of the end piece, not at the center. The bag was laid out, straightened, and rotated to put the valve on the ground. New on the back end piece, 180° from the front valve, was a bleed plug that is used to release air, and sometimes used for initial bag inflation and location.

The barricade construction always begins by spreading out the wedge bags. As they are strapped at three places, they define the layout of the big bags, as well as prevent them from rolling out. Based on the lesson learned from the wedge bag deflation and bag roll out, the bottom bags were further restrained by two straps slipped around them. A ground bag was put against the away wedge bag and filled from a fire truck that pumped water through a powder mixer device. The water gellant was Stockhausen AP85 in four 50-lb bags of powder. Since the water volume was also about double the volume of the 36-in bag, the gel was 1-2% by weight, the same range as before. Filling the second ground bag did not produce any push that would roll the first bag against its wedge and tighten the

ground pair. In fact, the second bag climbed and partly hung over its wedge bag; efforts to drop it inside the wedges were not successful. The problem was that the wedge bag straps were a bit short. The supplementing straps allowed the upper bag to nestle in the declivity of the two bottom bags, but not force them apart. (Later during firing, being unstrapped itself, this top bag rolled off of the deflating pyramid.)

The powder mixer in Figure 7 was new, untested, and troublesome to use. A bag of powder was slowly poured into the hopper as someone turned a crank, so that a mixing screw in a 45° tee pipe carried the powder into a straight section of flowing water. The powder tended to gel in the screw column, causing the turning resistance to become so high that 30 s of cranking would exhaust a man. Manual cranking was grossly inadequate for the filling task, so a 3/4-in electric drill was adapted to attach to the screw shaft. A material flaw was that the retainer cap at the end of the screw tunnel was plastic and was soon chewed up by the screw. A metal cap was bought and drilled for the screw shaft. Water also tended to gel in the hose, requiring frequent stops for cleanout. Every time the drill bound up, the mixer was disassembled and cleaned. As the causes of the problems were anticipated, various alterations provided longer run times before the drill bound. Screw tip depth was sensitive; it was adjusted to just poke into the mainstream. Reducing pump pressure and changing from a 3-in hose to 2-in hose brought the flow rate down from high to moderate and introduced turbulence in the mixing chamber. Lastly, the mixer was lifted on a fork truck platform to gain better flow. With the right flow-rate conditions, drill speed (moderate revolutions per minute), and screw depth, the mixer performed satisfactorily. Using a mixer is far better than hand pouring the powder down the barrier bag and shaking it.

The top bag was almost filled when a pop was heard. The sound was caused by the rupture of the inner bladder that holds the gel water. Numerous streams jetted from the bag along its length, but eventually, it became noticeable that the streams were ending. The gel formed in the small holes of the weave, stopping the leaks. The bag seemed all right, and it was left overnight in the hope that it would hold adequately. The bag held, they were topped off in the morning, and the test was performed that afternoon. The filling took two very long days. To avoid the risk of a test-ending bag rupture, the bags were intentionally underinflated; the barrier height was below 7 ft.

5.2 Firing. There was one change to the explosive train of Section 4.2— a different detonator, a single RP83 exploding bridgewire was used. The biggest operational problem in the 36-in test was that the gel was so fluid that it overflowed the firing position. Its slippery coverage made it impossible to continue after four shots or about 15 min. For the 54-in test, the bags were raised on a ramped mound, and the firing position was up stairs on heavy plates supported by a steel table (see Figure 8). The idea was that incomplete gelling would only put the flowing contents from the pierced bags under test height, and the shots could go on. So, nine rounds were fired, although fewer would have sufficed to find the effectiveness of the barricade. As before, projectile positions were premarked on a line on the table, 10 ft off of the bag. The firing positions are listed in Table 2.

5.3 Results. The shot-by-shot results for the 54-in bags are in the last column of Table 2 and are shown in Figures 9-18. For the first shot, the projectile was nose on, centered at midbag. The explosion put two large holes and five small ones in the front bag. The flow stopped before the second shot was ready (5 min). In the second shot, the projectile lay 2 ft left of midbag and turned 30° left, and its explosion produced a large hole and a tall shower of gel. The front bag drained quite low at the front end, which allowed the unrestrained top bag to roll over the slippery cover and slide into the firing table. With the weight of the top bag gone, gel flow stopped from the front bag. Beginning with the third shot, the barricade was a half-empty front bag and an inflated back bag. The projectile produced few fragments through nine shots, and the back bag was never hit. No 105-mm fragments got through a bag to hit the plywood witness boards. This result was expected, since none got through the 36-in-diameter bag either. The hand-sized pieces of steel case were found; they were the most destructive to the bag because they produced long, slicing tears instead of just holes.

Table 2. Results on 54-in-Diameter Bag Barricade

Shot	Projectile on 10-ft Separation Line	Remarks
1	centered, nose on to bag	Large gushing hole near front seam. Spouting hole just aft of midbag. Five dripping holes between. All holes self-seal.
2	-2 ft, turned 45° counterclockwise (CCW)	Large tear on ground bag and large plume of gel, twice bag height. Extends above and beyond table. Weight of top bag squeezes more gel out of end tear. As the ground bag deflates, the top bag rolls off the mound and is stopped by the table.
3	3 ft, turned 30° CCW	Ground bag is half deflated, but back bag is still up.
4	-1 ft, turned 60°CCW	Front bag hit again, good splash. Three spaced holes oozing from fill end. Barricade height is 3 ft.
5	-3 ft, rear on	No sign of impact. Fourth hole begins to ooze.
6	3 ft, turned 45° CCW	Fragment splashes into mound itself in front, three-quarter view.
7	3 ft, side on to bag	Good gel splash. Two nearby gel droplet fronts seen, implying two fragment hits. Back bag gets at least one of the hits. Bag is down greatly in front. End view shows two vertical sprays. Probably one hit on each bag. Only 7 minor leaks (oozes) on upper bag at start of shot 7. Back bag's front is laid open to half-length.
8	1 ft, turned 60° CCW	Fragment hit in big gel puddle of slashed open end. Fireball and spray well separated. Back bag 3 ft high at rear.
9	-2 ft, nose on to bag	Good splash. Fragment caught the front bag and ripped it wider

6. Conclusions

The following lessons were learned from this cookoff hazard test:

- The bags can be set up and filled safely.
- It is better to wrestle a few bags (3) than many bags (6).
- If the wedge bags' straps are the correct length, the barricade layout is self-locating.
- Water weight will nestle the bags together.
- The wedge bag is extremely important to stack unity, and it should be protected with field expedients like angle iron or sandbags.
- The stack will roll down if a wedge bag deflates, or if the outside ground bag deflates. The side of the barricade exposed to the ammunition stack is at risk.
- Backup straps should be put around the bags to prevent rolling.
- Preferably, the powder will be mixed through a hopper during water fill. Smooth equipment operation can be developed.
- The gel is thinner than bench tests indicated. Due to crude dispersal, an unexpected increase in flow occurred, and gelling was uneven.
- The Stockhausen AP85 gel causes no environmental harm, but approval to use it at the experimental facility is constrained by laborious scoopup and barreling requirements.
- Few fragments were sent towards the stack.
- Small fragments make inconsequential holes in the bags; hand-sized pieces make slashing rips that cause emptying and height loss.
- No fragment passed through the bags and hit the witness board.
- Less than 36 in of gel will stop a 105-mm projectile fragment.
- The released gel may have a firefighting benefit, which is to smother the fire.
- The gel can be liquefied with road salt, simplifying the cleanup and bag recovery.
- The gel is very slippery, making walking hazardous.

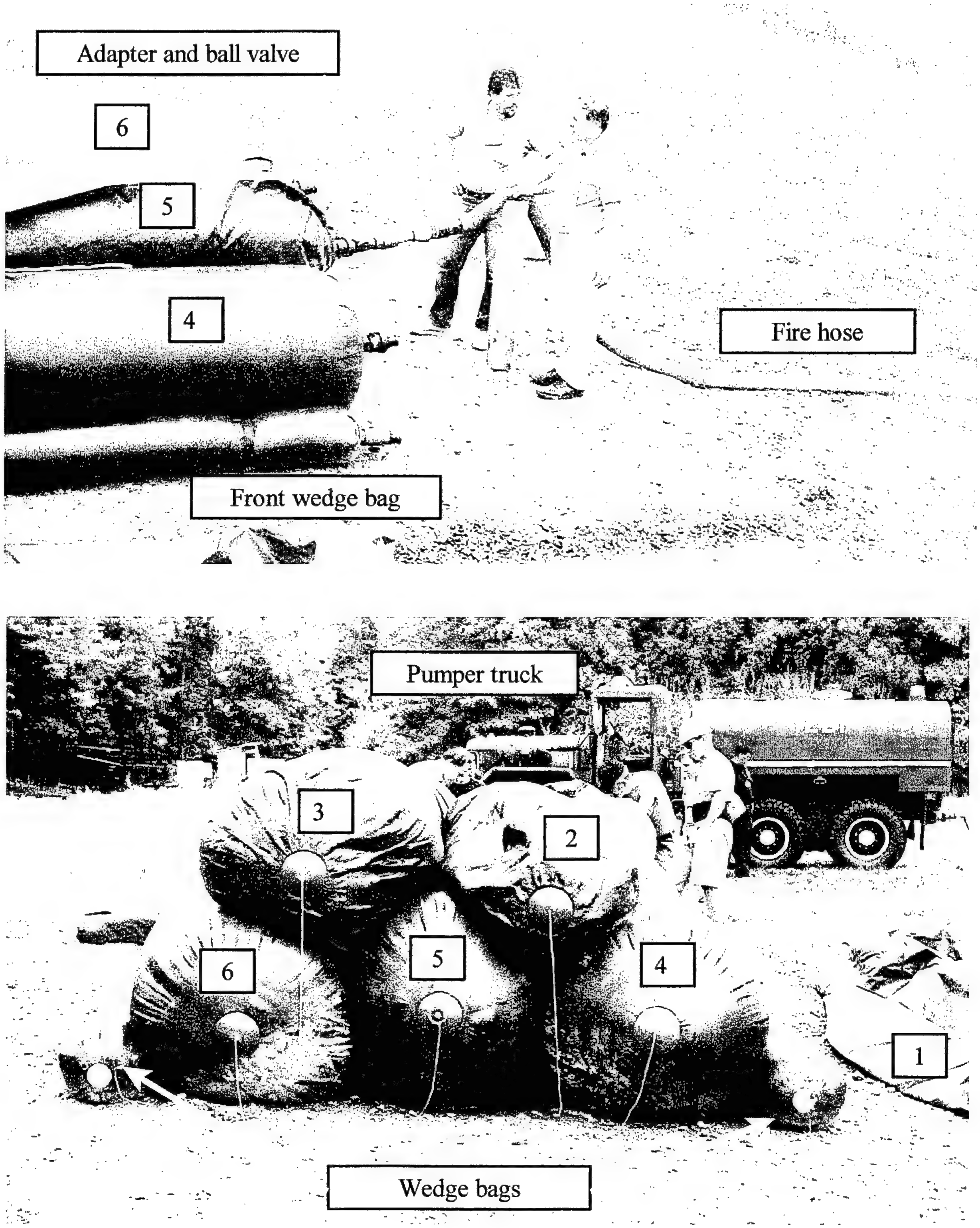
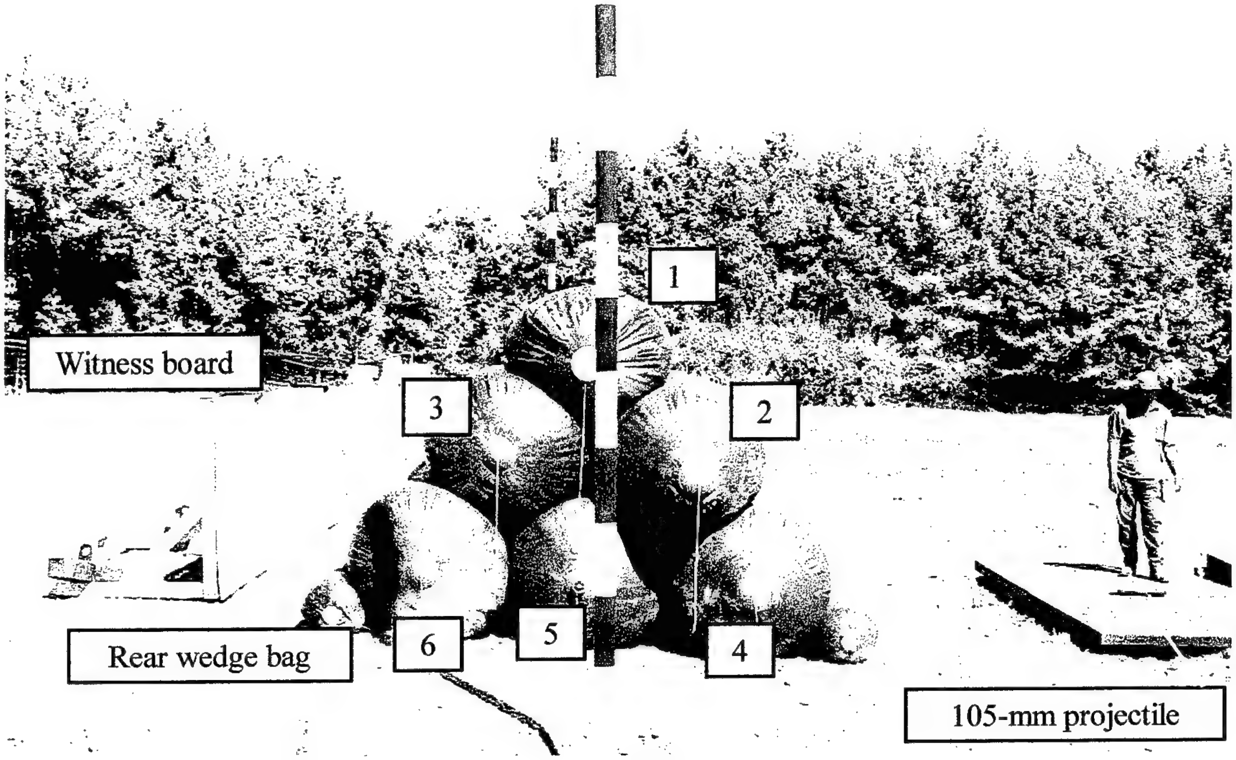


Figure 1. Setting up the 36-in-Diameter Bags: Filling the Ground Layer (Top) and Filling the Second Layer (Bottom).



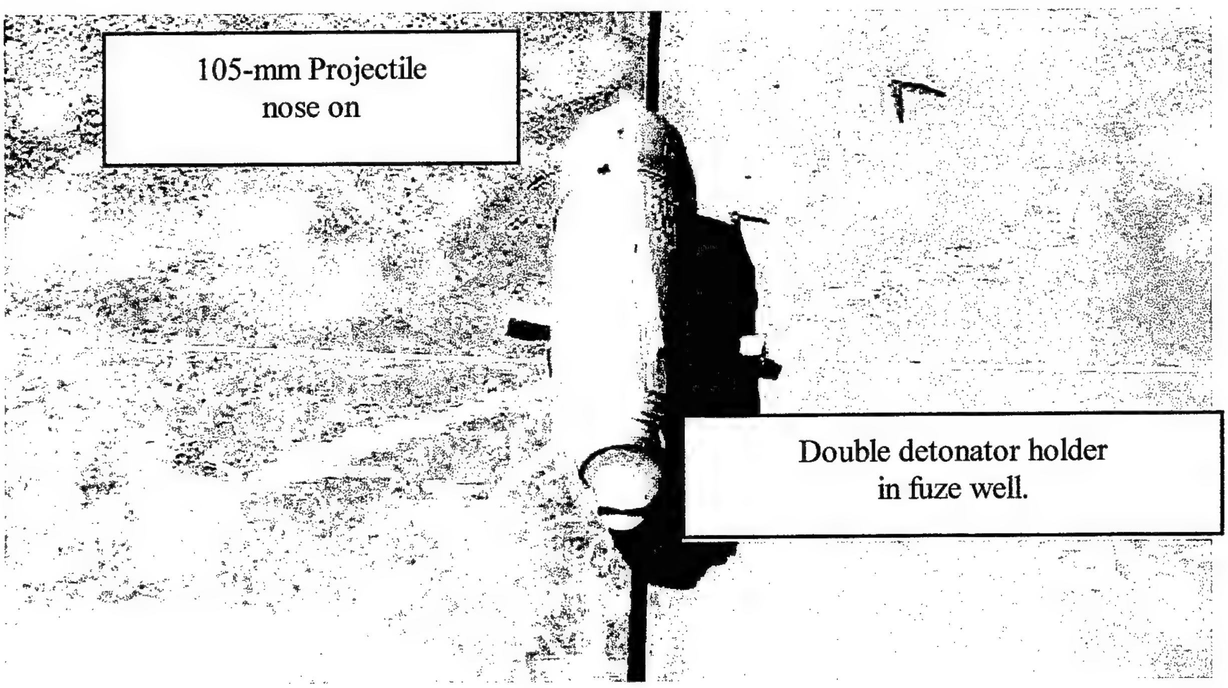


Figure 2. Setup for Shot 1, 36-in-Diameter Bags: Overall Setup (Top) and with 105-mm Projectile Nose On (Bottom).

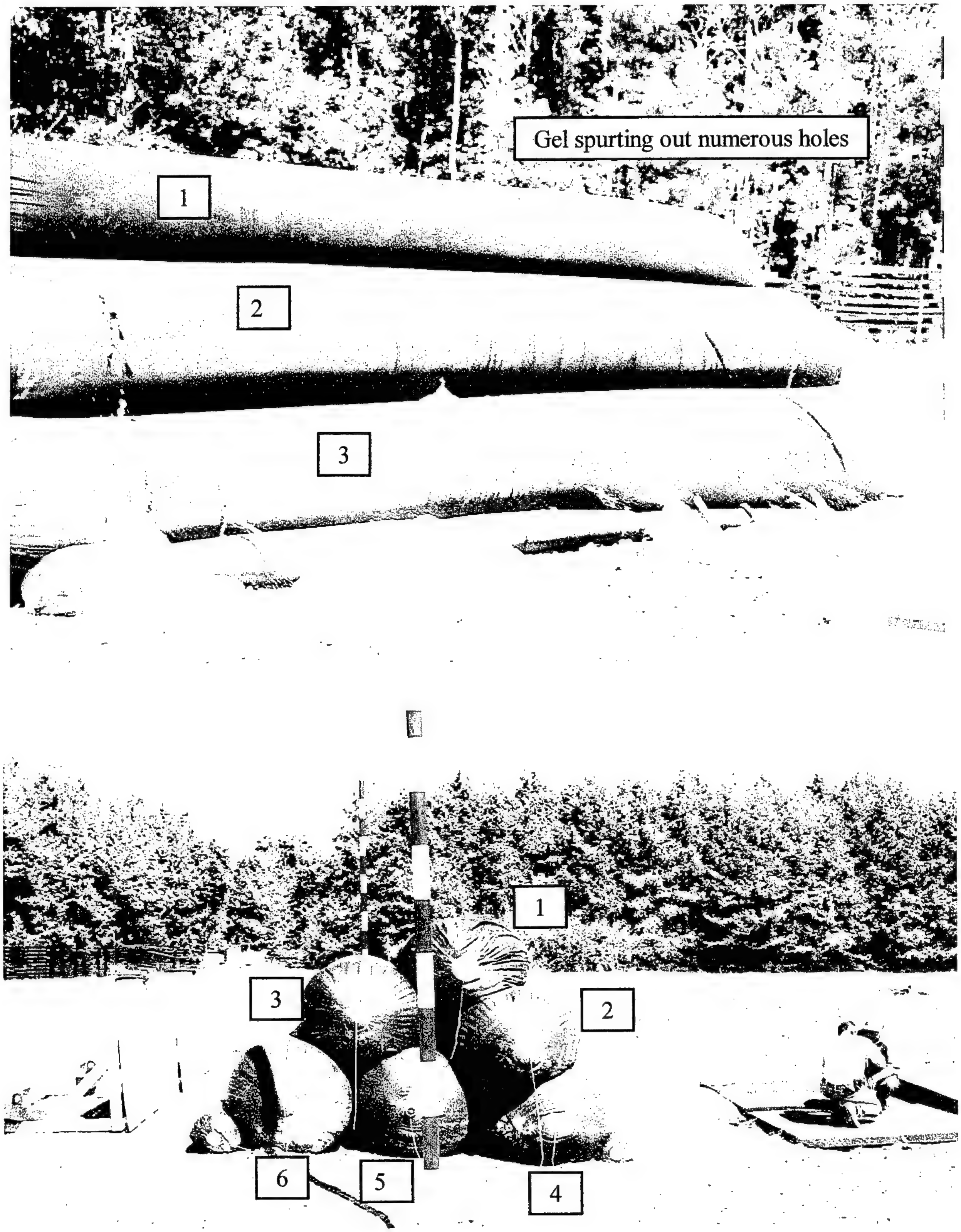
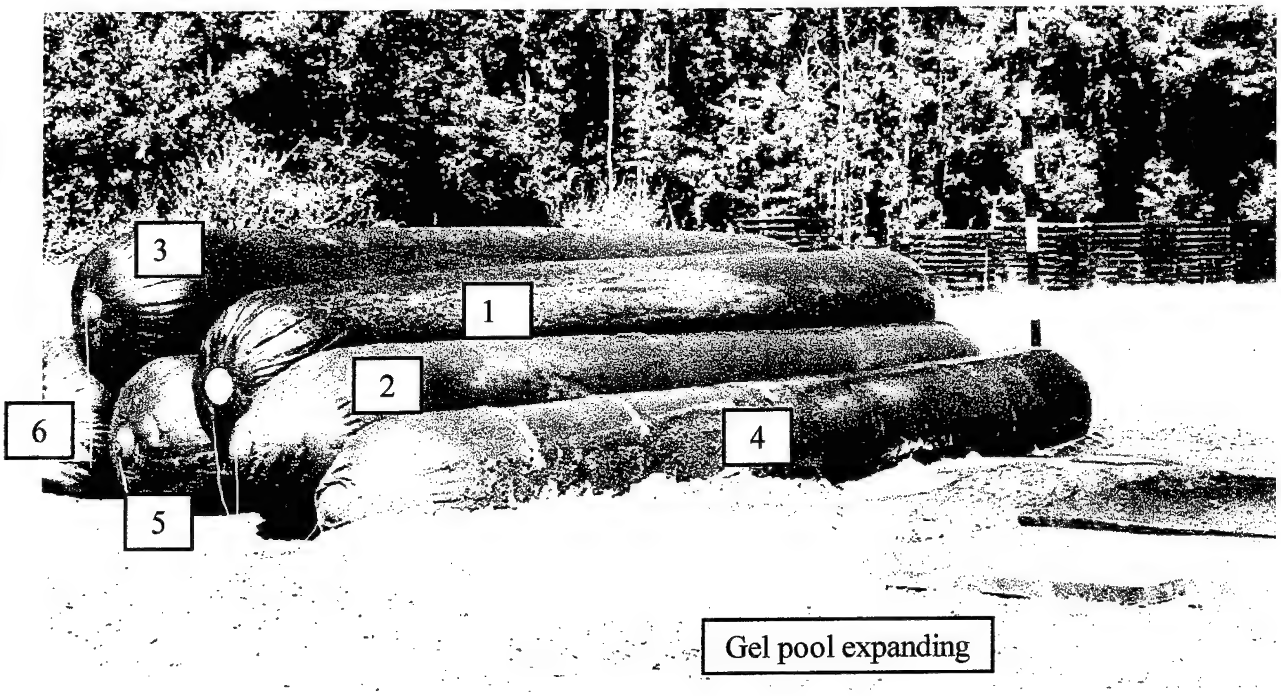


Figure 3. Result of Shot 1, 36-in-Diameter Bags: Rear-Quarter View (Top) and End View (Bottom).



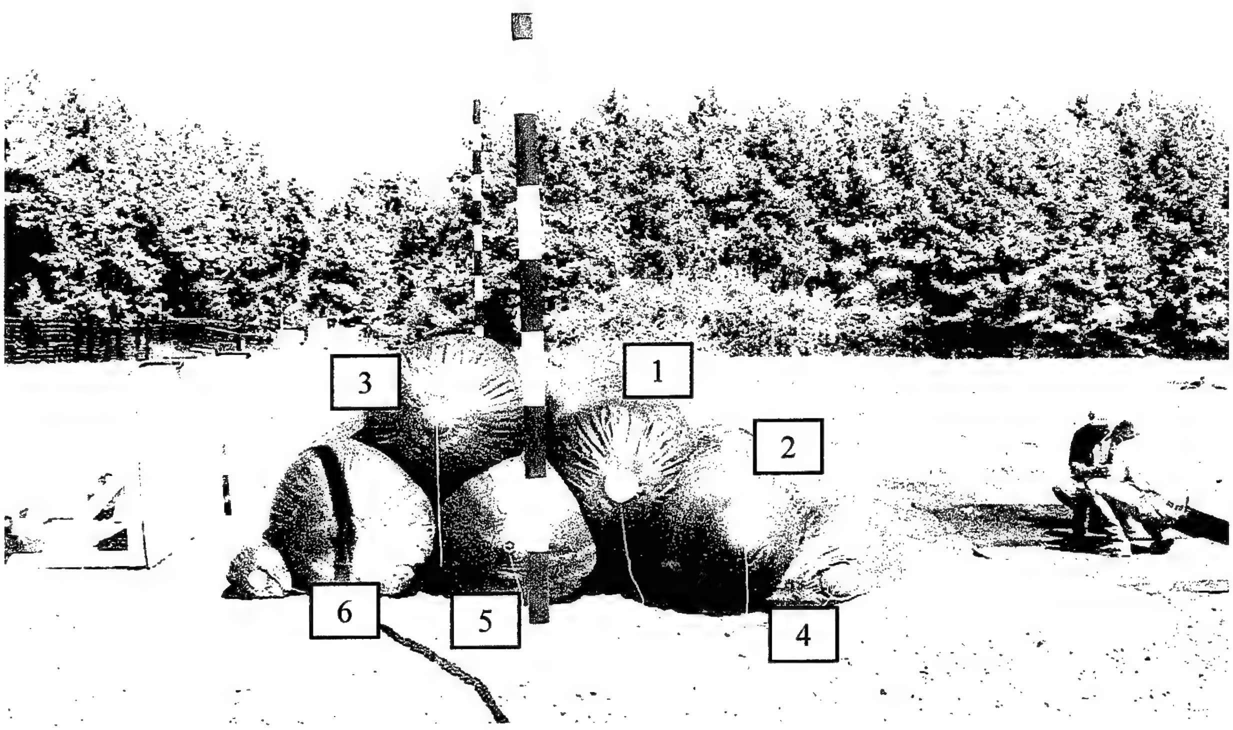


Figure 4. Result of Shot 2, 36-in-Diameter Bags: Rear-Quarter View (Top) and End View (Bottom).

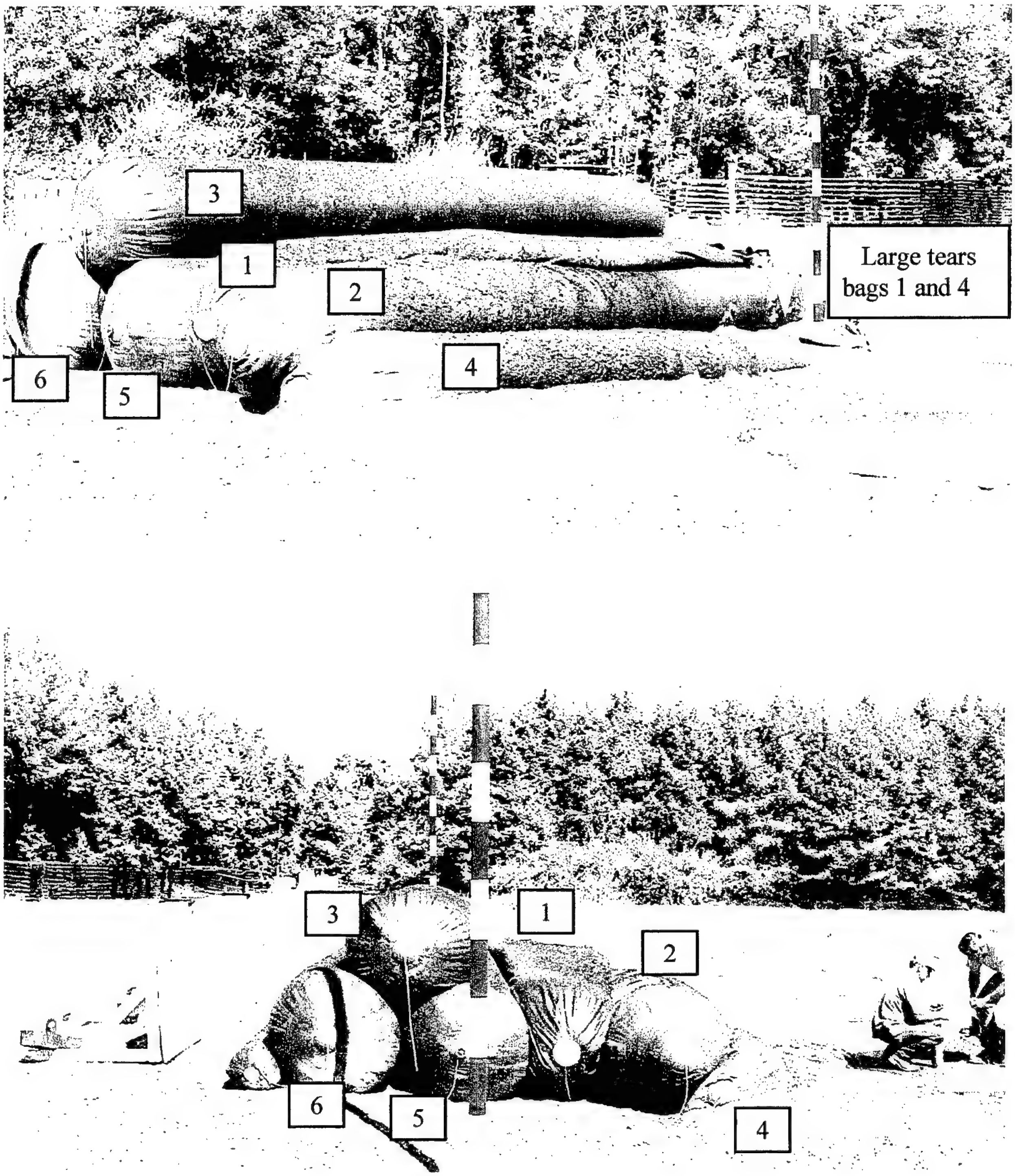


Figure 5. Result of Shot 3, 36-in-Diameter Bags: Rear-Quarter View (Top) and End View (Bottom).

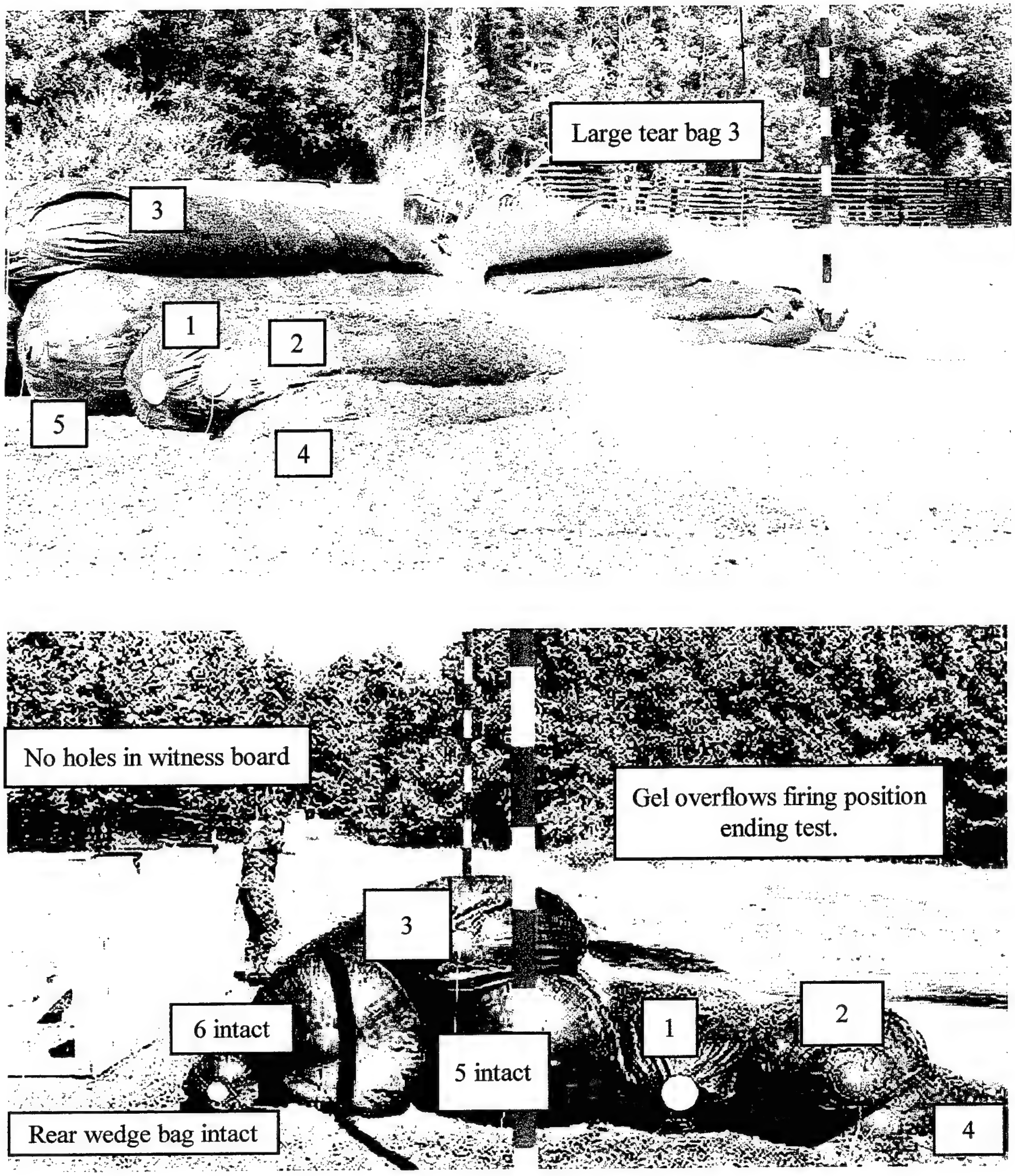


Figure 6. Result of Shot 4, 36-in-Diameter Bags: Rear-Quarter View (Top) and End View (Bottom).

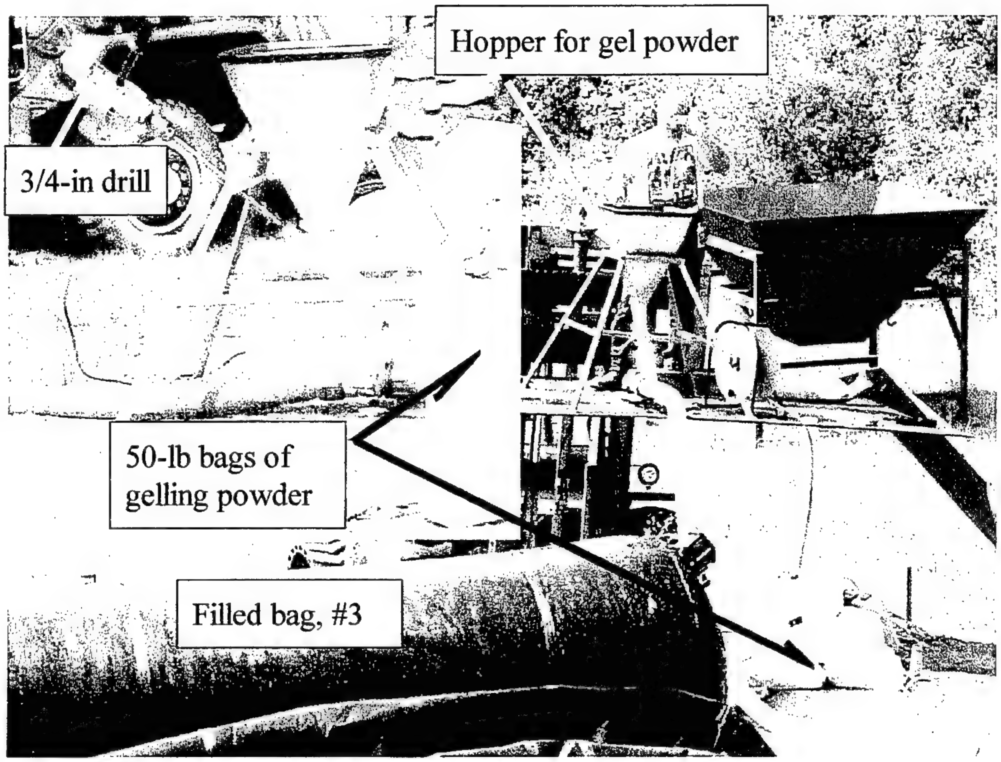


Figure 7. Use of Gel Powder Mixer.

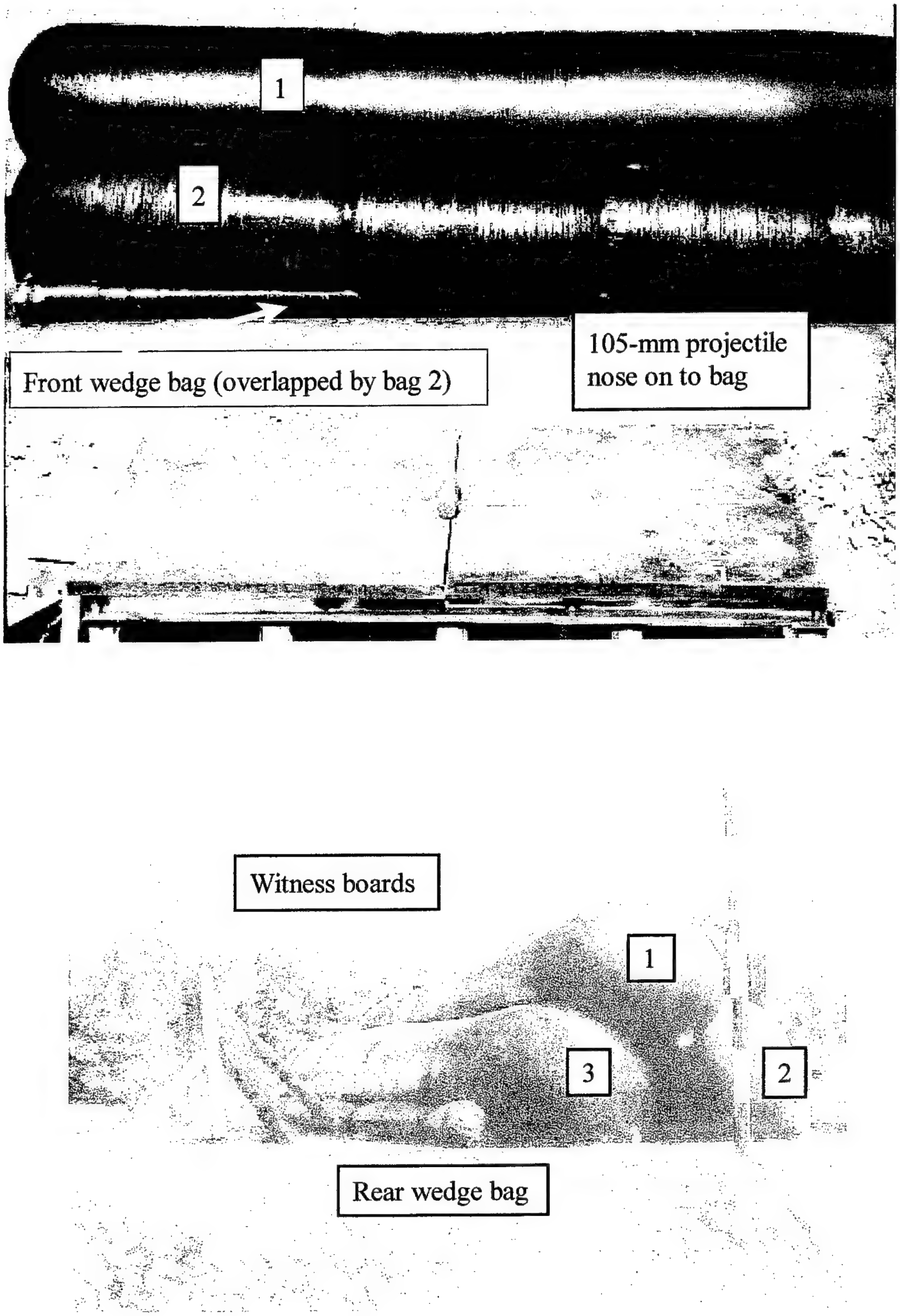


Figure 8. Setup for Shot 1, 54-in-Diameter Bags: Side View (Top) and Rear-Quarter View (Bottom).

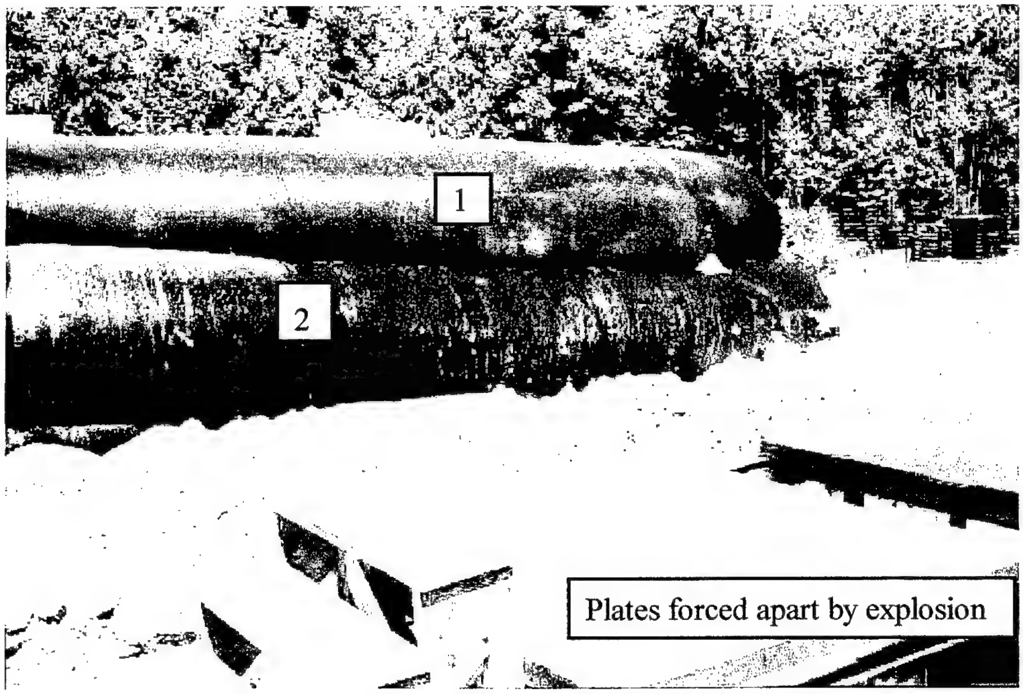
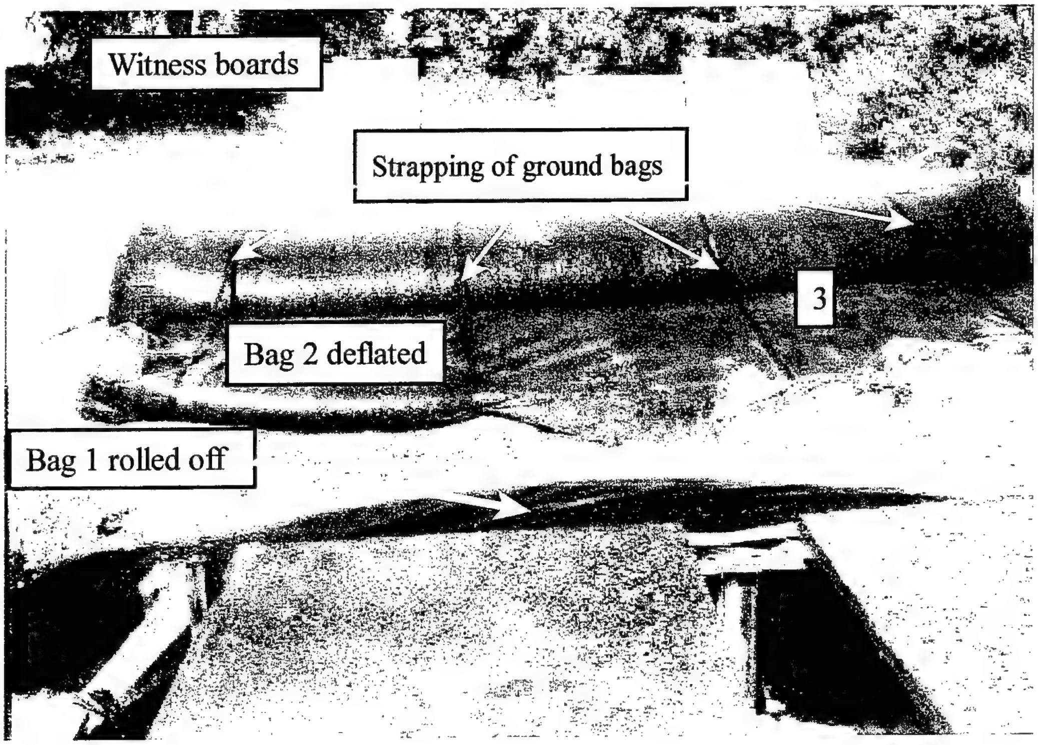


Figure 9. Result of Shot 1, 54-in-Diameter Bags.



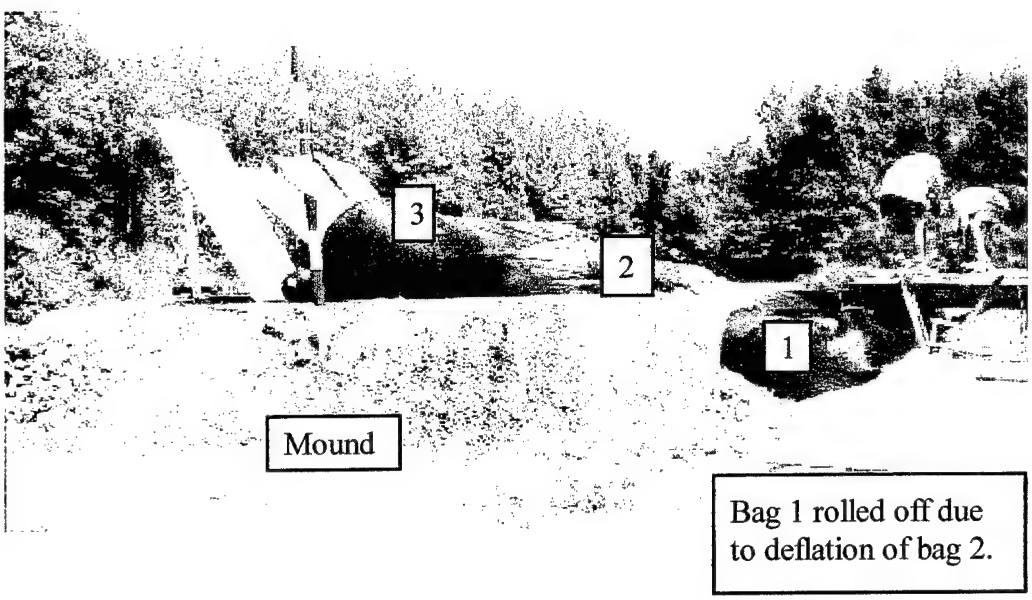


Figure 10. Result of Shot 2, 54-in-Diameter Bags: Side View (Top) and End View (Bottom).

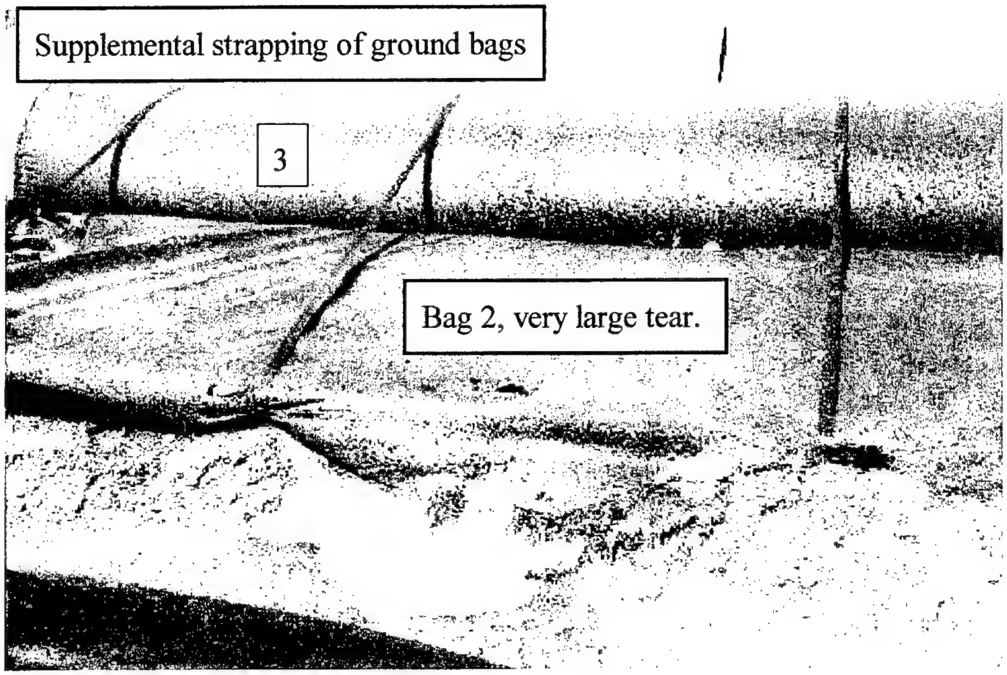


Figure 11. Result of Shot 3, 54-in-Diameter Bags.

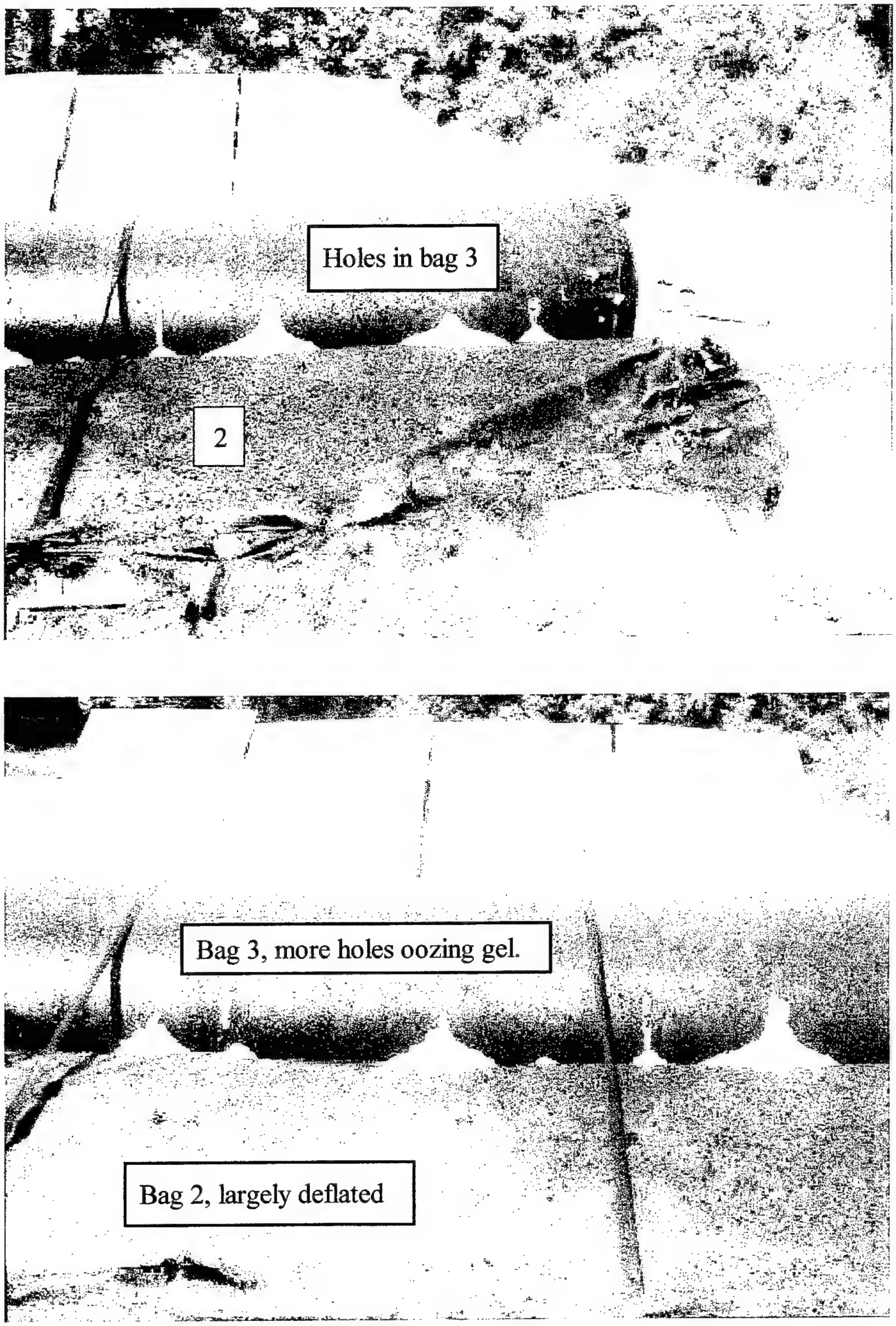
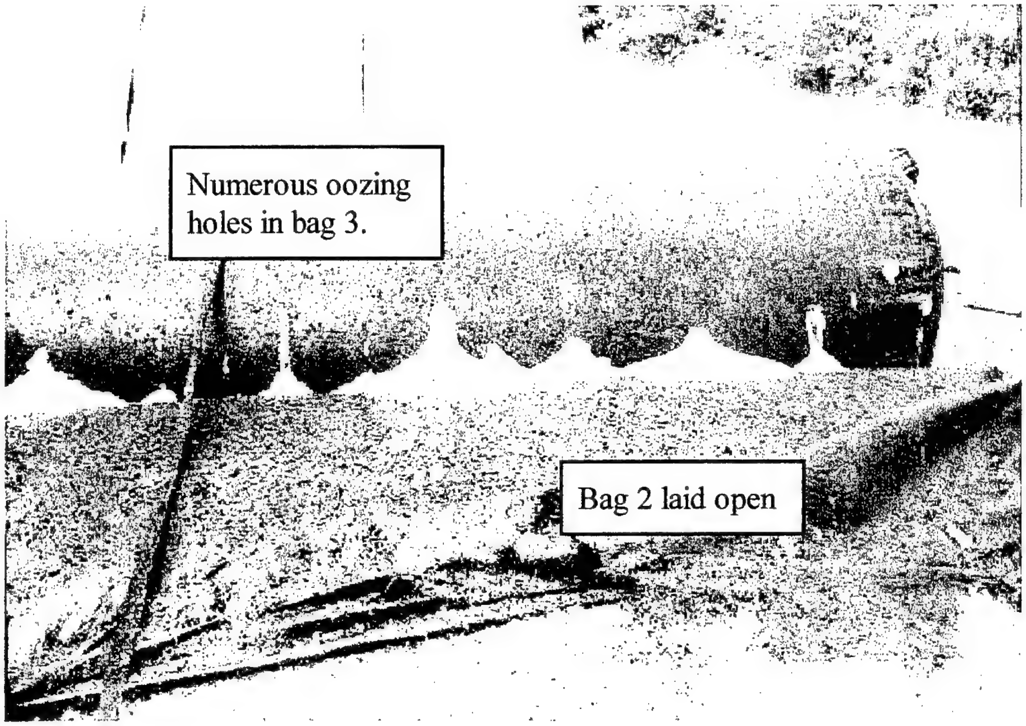


Figure 12. Result of Shot 4, 54-in-Diameter Bags: Midbag Views.



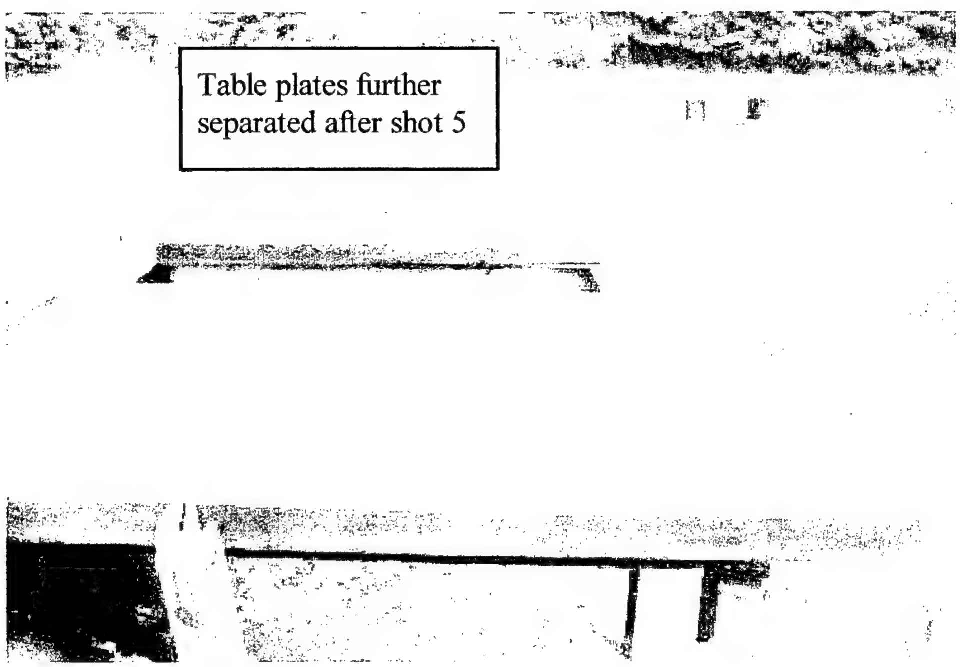


Figure 13. Result of Shot 5, 54-in-Diameter Bags: Side View (Top) and Table Separation (Bottom).

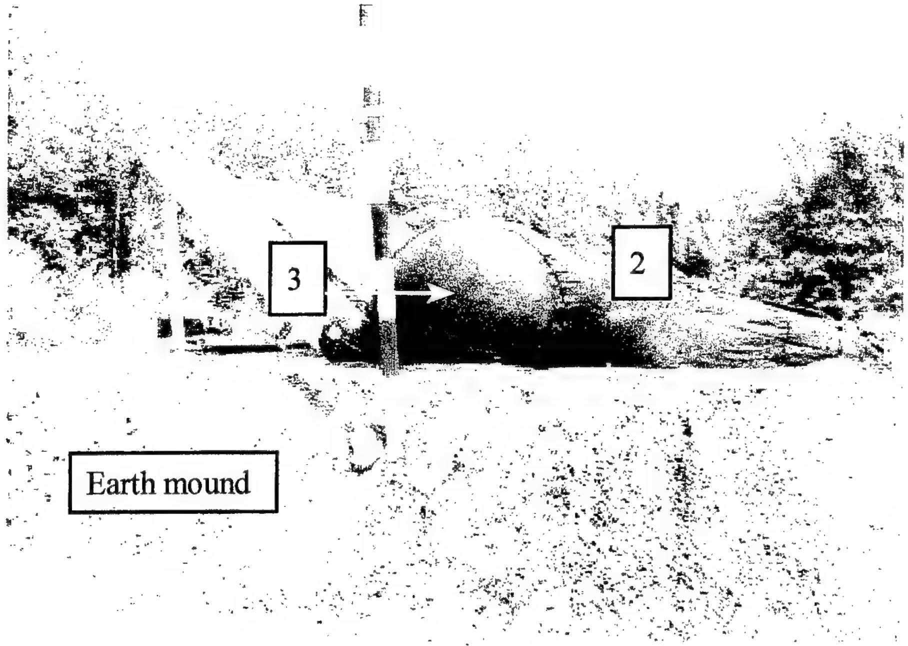


Figure 14. Result of Shot 6, 54-in-Diameter Bags.

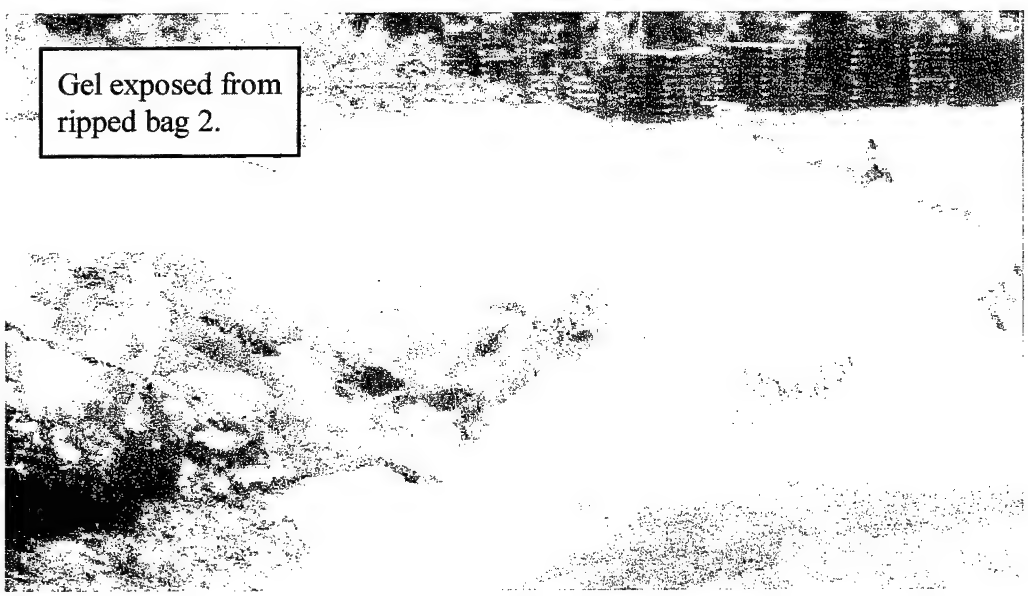


Figure 15. Result of Shot 7, 54-in-Diameter Bags.

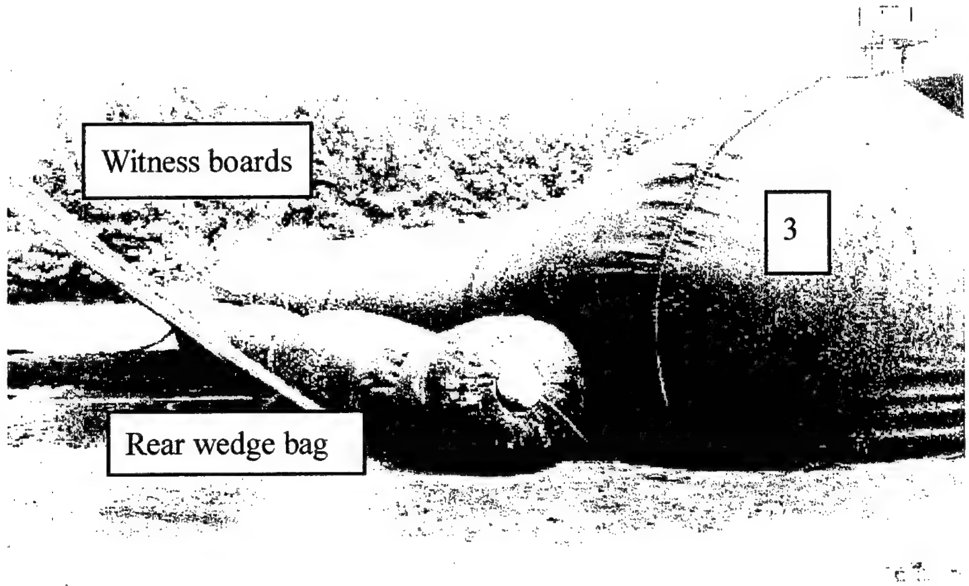


Figure 16. Result of Shot 8, 54-in-Diameter Bags.

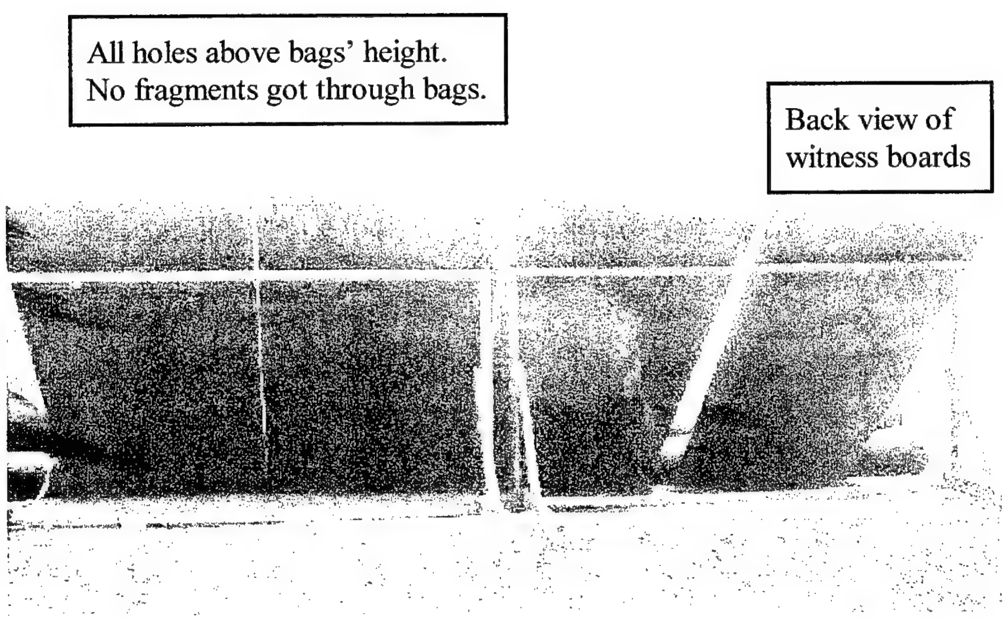


Figure 17. Result of Shot 9, 54-in-Diameter Bags.

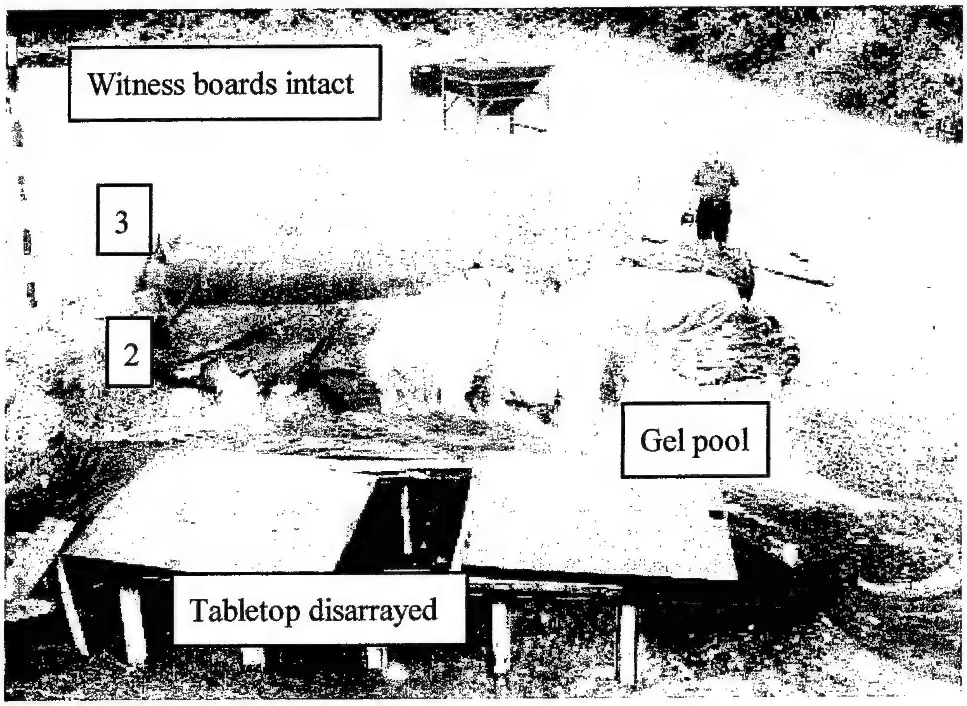


Figure 18. View After Nine Shots on 54-in-Diameter Bags.

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Appendix :

Operations Plan for 36-in-Diameter Bags

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Test Plan
Water Gel Barricade
21 August 1998

Objective: Fire live shells near a six-bag, water gel barricade and observe effects on bags and witness boards.

Location: Mound, R-12, Spesutie Island, Army Research Laboratory, APG, MD

Date: Week of 14 September 1998

Plan: See sketch (Figure A-1) of test layout. Disperse superabsorbent powder (6 x 100 lb) into six bags and two bottom wedge bags. Pump in water from fire trucks, bag-by-bag, to form a 3-2-1 triangular barricade of bags (3-ft diameter x 24-ft long bag); wedge the bottom row outside with small diameter wedge bags. Do not overinflate the bottom row! Inflation will take one day, if there are no problems.

Station (2) supported plywood sheets 3 ft behind the barricade to act as witness plates for fragments traversing the barricade. Lay a 105-mm HE projectile 10 ft from the barricade. The complete cartridge (DODIC C445) will not be used.

Initiate the projectile with dual firing lines carrying very high voltage to 2023 detonators inserted into boosted C4 in the fuze well. Precut the replaceable sections of the firing line.

Record the shot effect by using ground level and elevated television cameras viewing the barricade and height poles. When the test director releases test personnel from bunker cover, do a walkaround with a video camera and a still camera. Visitors are to remain under cover.

Change plywood if it is badly fragged.

Set the next projectile according to a selected, semi-random schedule to simulate the scatter of projectiles from a pallet accident. For example, randomly place the second projectile along the 10-ft spacing line at a distance of 1-4 packing boxes from the first projectile's placement, and randomly orient the projectile nose 0°, 30°, 45°, 60°, 90°, ..., 360°. Fire the second projectile at +6 min. Maintain a rate of 1 shot/6 min for10 shots.

Terminate the test before the tenth shot, if the barricade grossly fails. Otherwise, continue video recording to observe possible slow bag deflation.

BARRICADE LAYOUT

10 Shots, 1/6 min

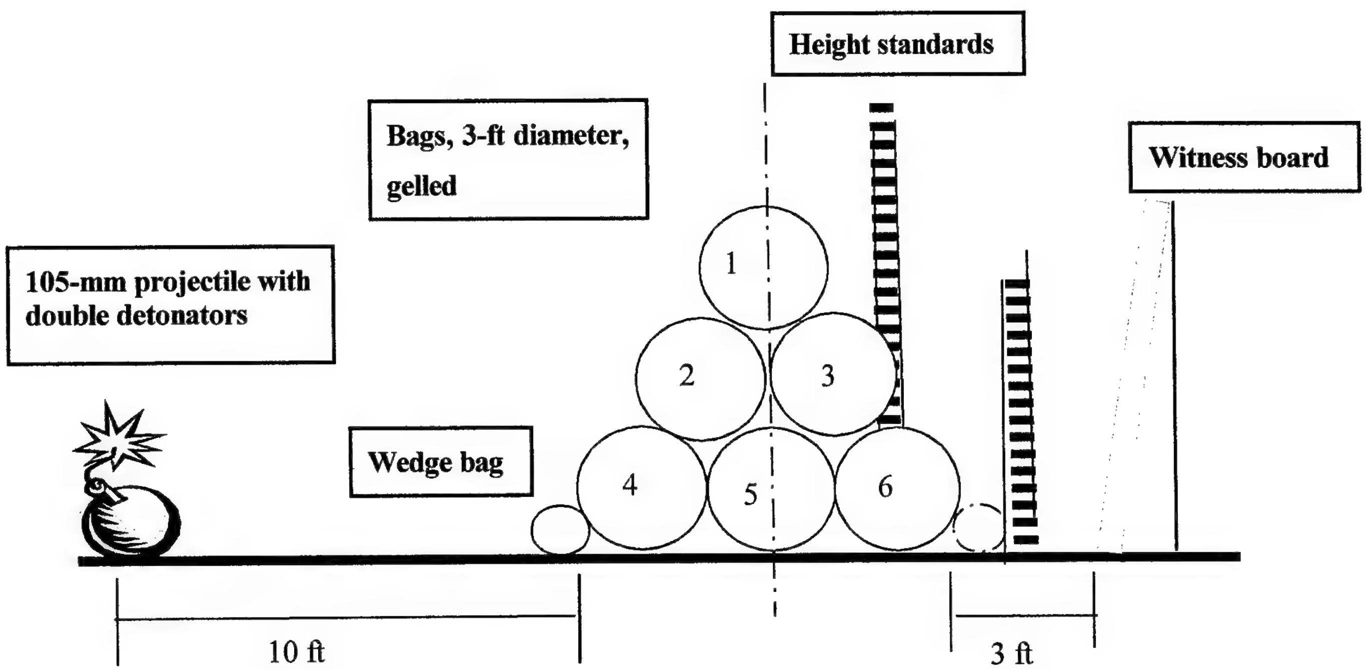

Figure A-1. Sketch of Test Setup for 36-in-Diameter Bags.

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Large tubular bags of water gel were tested as expedient barricades to provide protection against the effects of ammunition cookoff. The tests explored the feasibility of this concept for a program called Munitions Survivability Technology by the Defense Ammunition Logistics Agency. Primarily, the tests aimed to see if the bags could survive yet stop fragments from a time series of ground-exploded 105-mm high explosive (HE) projectiles. Second, the tests were used to evaluate the construction of the barricades. A six-bag (36-in diameter) and a three-bag (54-in diameter) linear pyramid barricade were constructed and subjected to four and nine rounds, respectively. The immature development state caused gel mixing and bag leakage problems, which were overcome. A single 36-in bag stopped a 105-mm fragment; however, the flow (runny gel) soon lowered the barrier height, losing protection against further cookoffs. The front wedge bag deflated and caused the incompletely restrained row above to roll down and drop the barrier height. The 54-in bags were easier to set up because there were fewer of them, but they reacted the same as the smaller bag barrier. The front ground bag deflated soon after the second shot (+6 min), and the top, unrestrained bag rolled down. Again, no 105-mm fragments got to the witness boards, but the barricade height was only about one partially deflated bag high.

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